Andrews (E,)

REPORT

ON THE

FUNCTIONS OF THE CEREBELLUM.

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BY

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FUNCTIONS OF THE CEREBELLUM.

In preparing this report, the writer has confined his attention to that class of evidences which is to be found in the field of comparative anatomy, reserving the pathological and experimental proofs until another opportunity.

The cerebellum is a complex organ, and probably contains the nervous centres of several functions whose nature and limits are not yet very well defined. If it be viewed from above, it will be seen to present three lobes, one median lobe, or vermiform process, and two lateral lobes, Fig. 1. This division of the upper surface into three lobes is traceable throughout the Mammalia, the Aves, and the Reptilia, as I will show hereafter, though the existence of the division in the latter class has been generally denied. The three lobes are sometimes simple, but oftener divided into a number of lobules and the lobules again into laminæ. Upon the inferior surface the cerebellum presents the same number of divisions as upon the superior, but with a different relative position. Beneath the median lobe is the cavity called the fourth ventricle, on either side of the ventricle are the peduncles. In the mammalia at least the peduncles are six in number, two anterior, two middle, and two posterior, all, however, more or less adherent at their edges, so that there is no space between those of the same side. The anterior peduncles seem to belong especially to the median lobe. According to Serres, they vary in size in direct ratio with the bulk of that lobe. They run forward and connect with the rest of the cerebro-spinal axis beneath the tubercula quadrigemina. They are known in human anatomy as the *processus e cerebello ad testes*. The middle peduncles arise in the lateral lobes apparently, and running under and through the medulla oblongata form the prominence called the *pons Varolii*. They meet in the *pons* and constitute the commissure of the lateral lobes.

The posterior peduncles of the cerebellum also appear to belong to the lateral lobes, and running backwards they become continuous with the restiform bodies of the medulla. It is important to notice here, that the median lobe has its own pair of peduncles, its own commissure (valve of Vieussens), and its own attachment to the cerebro-spinal axis *in front*, while the lateral lobes have their own pair of peduncles, their own commissure, and their own attachment to the cerebro-spinal axis at a point further backward, showing apparently that though in mammalia the lateral lobes are located on each side of the median, *yet their archetypal position is posterior to it.* We shall see in the reptiles the cerebellum actually analyzed by nature, and the lateral lobes existing as separate organs, though not hitherto recognized as such by comparative anatomists.

The muscular system of mammals and birds, is the part upon which the cerebellum obviously exerts most of its influence, whatever that influence be. The muscular system of these animals is mostly collected into two groups or masses, viz., the group concerned in the motions of the anterior extremities, and the group which acts upon the posterior extremities. Each of these groups receives separate innervation, and there is an enlargement of the spinal cord in the regions where the nerves to each are given off. With each group are probably to be classed the muscles of the contiguous portions of the trunk. Since, therefore, the two groups are thus separate, and connect with separate expansions in the spinal axis, it is not improbable at all, that the encephalic connection may also lead to separate centres, and if the cerebellum be an organ at all connected with motor functions, as it certainly is, there would be a certain amount of *a priori* probability, that the lateral lobes, which are properly the posterior, would preside over the muscles of the posterior group, and the median lobe in like manner exert their influence upon those of the anterior group.

As supporting this theory, I present the following propositions:—

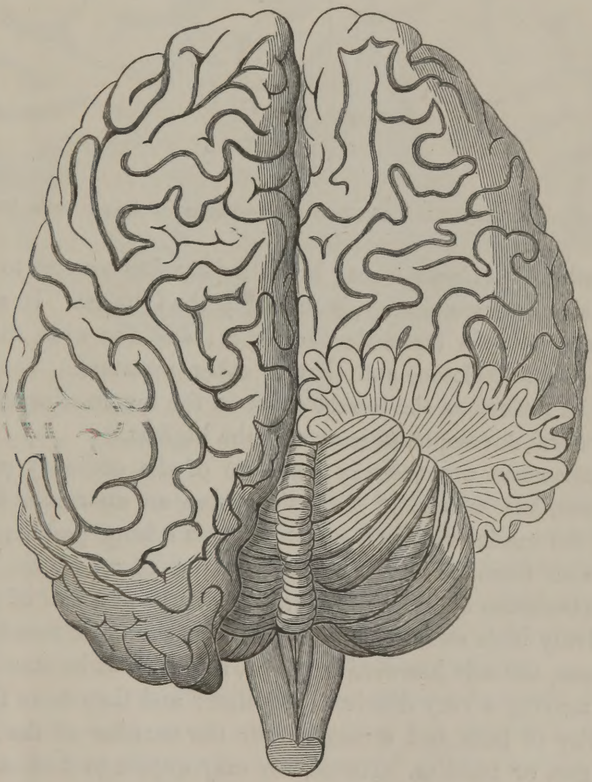
1. *In the warm blooded animals, the median lobe, or vermiform process of the cerebellum varies in size directly as the bulk and power of the anterior group of muscles.*

2. *The lateral lobes vary in like manner, as the power of the posterior group of muscles; subject, however, to certain variations hereafter to be mentioned.*

The figures which I offer in illustration of these propositions are from my own dissections, except where credit is given, and are carefully corrected by measurements upon the specimen, so that their accuracy may be depended upon.

Fig. 1 represents on a reduced scale the human encephalon, one posterior cerebral lobe being removed to show the cerebellum. It will be observed that the median lobe is much the smallest, being crowded between and overtopped by the bulkier lateral lobes. Corresponding to this difference, is the feebleness and small size of the muscles in the region of the superior extremities, as compared

Fig. 1.

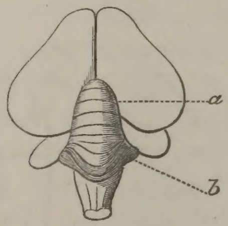


MAN. Diameter reduced one-half.

with the inferior. The whole locomotion is executed by the latter, while the arms are only used for lighter and more delicate labors.

If we compare with this the encephalon of a bird, we shall have a striking contrast. Fig. 2 is the brain of a gull—*Larus Bonapartii*—common on the western lakes. This bird has powerful wings, and feeble inferior extremities. Flight is an action which requires the utmost development of muscular power; accordingly in this, as in most other birds, the muscles which move the wings by far exceed in size all the other muscles of the body. Corresponding to this is the development of the middle lobe of the cerebellum, which overtops, and, in this view, nearly conceals the lateral.

Fig. 2.



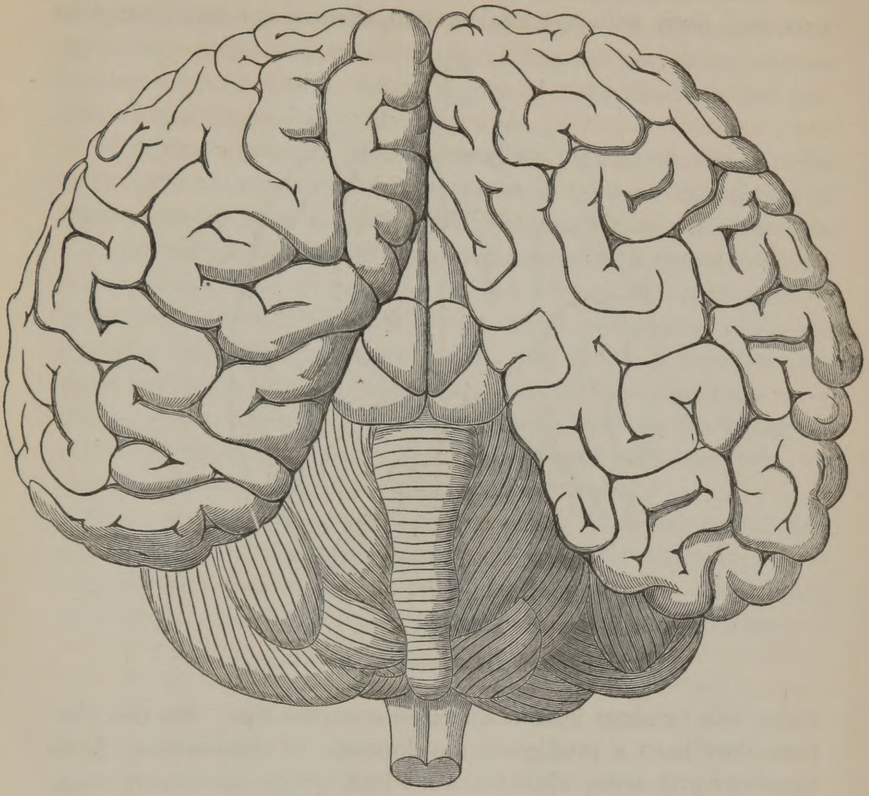
GULL—*Larus Bonapartii.* *a.* Middle lobe of cerebellum. *b.* Apex of lateral lobe.

The order of animals whose brain approaches nearest to that of man, in size and complexity, is probably the Cetacea. In external form, these animals resemble the fishes; and the wide difference between their skeleton, and that of other mammalia, has caused them to be ranked as the lowest order in the mammalian class, yet their cerebral development is among the highest.

The cetaceans are entirely destitute of the ordinary posterior extremities, but instead of them they have an enormous development of the caudal vertebræ which support a huge paddle, and are moved with force by a very powerful group of muscles. The anterior extremities are much feebler, and consist of a pair of paddles, of relatively little strength. The posterior group of muscles is, in the cetacea, the sole locomotive power, as much as in man himself, though moving a very different propeller; and they have the same superiority of bulk and strength over the muscles of the anterior extremities, or paddles. Hence, we may expect to find in them a similar proportion between the cerebellar lobes, as in man.

Fig. 3 represents the encephalon of the Dolphin. It is obvious at the first glance, that it conforms perfectly to the law, the middle lobe being overbalanced by the lateral, in the same decided manner as in man.

Fig. 3.



....PHIN. (From SERRES' Anatomie du Cerveau.)

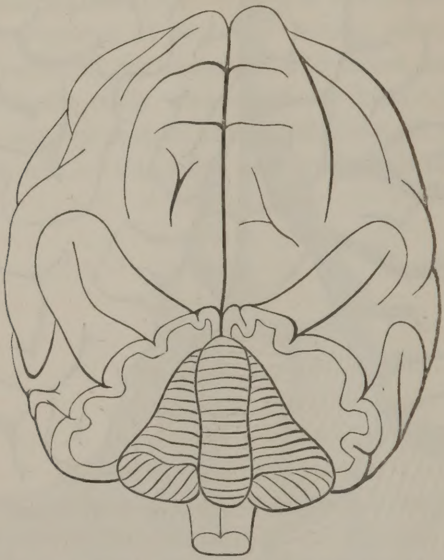
In the Mandrill, *Cynocephalus mormon*, a species of baboon, we find a greater development of the anterior group of muscles than in man, or the dolphin, and the posterior extremities, relatively less strong. Fig. 4 represents the brain of this animal, showing a marked increase of the relative size of the middle lobe, corresponding to the increased power of the anterior extremities.

If now we turn our attention to those animals in whom the anterior extremities are more powerful than the posterior, we shall observe a striking change in the proportion of the cerebellar lobes.

The family of Talpidæ, or the moles, are pre-eminently excavators, and are specially constructed with a view to their habit of piercing long passages in the earth. They accomplish this, not by carrying the earth out at the mouth of the burrow, as the marmots and squirrels do, but by a more rapid process. The mole thrusts

its broad, shovel-shaped hands into the earth, in front of its shoulders, and then, with a lateral motion, thrusts the earth away on

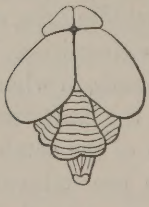
Fig. 4.



MANDRILL—*Cynocephalus mormon.* (From SERRES.)

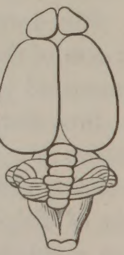
either side by sheer force of its anterior extremities. For this purpose, they have a prodigious development of the muscles of the shoulders and arms, while the hind legs are comparatively weak. In an individual of the genus Scalops, from Southern Illinois, I found the anterior extremities, with their muscles, to weigh two hundred grains, while the posterior weighed but sixty-six grains.

Fig. 5.



MOLE—*Scalops.*

Fig. 6.



RAT.

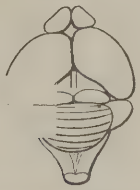
Fig. 5 represents the encephalon of this specimen, which, for the sake of comparison, is placed beside the brain of a common rat, Fig. 6.

It will be seen that, while in the mole the middle lobe of the cerebellum is the largest, because its *anterior* limbs are the most powerful in the rat, the lateral lobes are the largest, because its *posterior* limbs are the strongest. Other species of moles illustrate and confirm the law equally well.

Of all the mammalia, the bats are those in whom the anterior extremities most exceed the posterior in power. The action of flight requires great muscular strength; hence these animals have the same preponderance of the anterior group of muscles which we find in birds. In a *Vespertilio subulatus* I found the anterior extremities with their muscles to weigh thirty-two grains, while the posterior only weighed eight grains. In the bat, therefore, we should expect a great development of the median lobe of the cerebellum at the expense of the lateral lobes; while in the mouse, an animal of about the same size, but of stronger posterior limbs, we should look to find the lateral lobes predominant.

Fig. 7 is the brain of the red-haired bat, *Taphozous rufus;* and Fig. 8 is that of the common house-mouse, *Mus musculus*, and is placed beside that of the bat by way of contrast, the mouse being an animal in which the posterior extremities are the most vigorous.

Fig. 7.



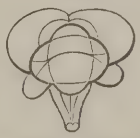
Red-Haired Bat—*Taphozous rufus.* Enlarged one diameter.

Fig. 8.

House Mouse. Natural size.

Fig. 9 is the brain of the little brown bat, *Vespertilio subulatus*, which, though differing in form, shows a similar predominance of the median lobe.

Fig. 9.



~~Silver-Haired~~ Bat—*Vespertilio subulatus.* Enlarged one diameter.

In birds, the general form of the cerebellum exhibits but little variety. That of the Gull, Fig. 2, will represent approximately the

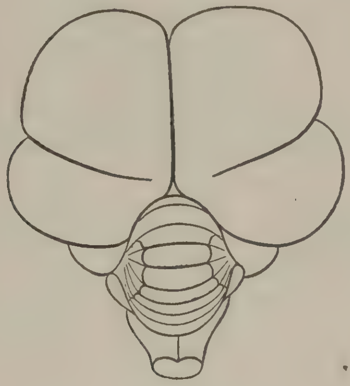
form in every species, from the ostrich to the swallow. In general, there appears to be a very marked predominance of the median lobe corresponding to the immense development of the muscular apparatus which moves the wings.

There is, however, a peculiar difficulty in comparing them with each other, owing to the obscurity of the line of demarcation between the lobes, so that it is generally not easy to define their boundaries. The cerebellum of all the birds is high in the middle, and much compressed laterally. On each side there is a small tubercle, which most anatomists consider as the sole representative of the lateral lobes. These tubercles are separated from the median prominence by a shallow semicircular groove which surrounds them, and which is usually taken to be the boundary between the lobes. But the fact that this groove maintains about the same position throughout the whole class of birds, regardless of changes in every other part of the encephalon, and the fact also that it exactly corresponds to the ridge on the inner surface of the skull formed by the projection inward of one of the bony semicircular canals of the internal ear, is ground enough for belief that it is a groove impressed upon the cerebellum from without, and does not represent any physiological boundary within.

The semicircular canals of the internal ear of birds are of great size, and with the cancellar structure surrounding them they occupy a very considerable space. The semicircular canals in a hawk are absolutely twice as large as those of a man, or nearly so. Accordingly, two thirds at least of the whole lateral diameter of the bird's head in the back part is occupied by the bony labyrinths of the ears. If the cerebellum, therefore, had the same relative lateral diameter as obtains in the mammalia, the addition of this immense auditory apparatus upon either side would give the skull a preposterous width, and seriously impede its actions in seizing its food, etc. The uniformly compressed shape of the cerebellum is, therefore, to be accounted for on teleological grounds. Two of the canals form projecting semicircular ridges on the internal walls of the skull, one upon each side. Beneath the arching ridge is a little pit or cavity. This little pit receives the lateral tubercle of the cerebellum, and the arched ridge or semicircular canal above it impresses upon the cerebellum the groove which surrounds the tubercle. It is evident, therefore, that the semblance of three lobes in the cerebellum of birds must be taken with some allowance, and not too implicitly relied upon. Owing to errors caused by this

appearance, I am satisfied that too little substance has hitherto been allotted to the lateral lobes in birds, and that the real boundary between them and the median lobe must be sought for nearer to the mesial line. I have sought in vain in most of the birds for any clear mark of division, but have found it in only one species at all distinct. Fig. 10 is the encephalon of the snowy owl, *Stryx nyctea*.

Fig. 10.



SNOWY OWL.

In this case there was a slight but perceptible division between the median and lateral lobes of the organ, as may be seen by the figure. It was located nearer to the mesial line than the groove [illegible] semicircular canal, and consequently allowed more bulk to be assigned to the lateral lobes, though the median lobe was still predominant in size, corresponding to the power of the muscles of flight.

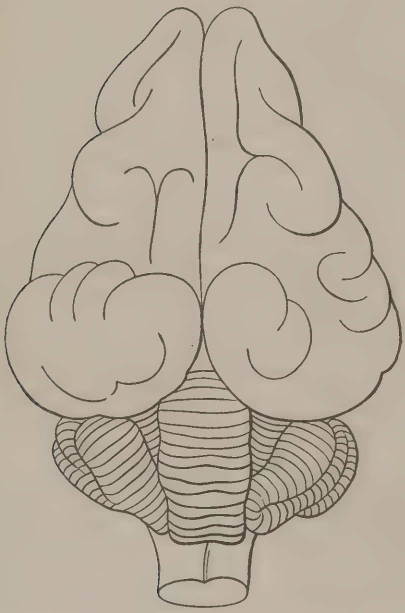
In the first part of this report, I alluded to certain exceptions to the law of the relation of the lateral lobes to the posterior group of muscles. Comparison shows, that while the lateral lobes have a certain correspondence with the group of muscles before mentioned, they have a not less striking ratio with the size of the hemispheres of the brain, and the rank of the animal in the scale of intelligence. There are, therefore, two conditions governing the lateral lobes as to size, which may be illustrated by three propositions:—

1. If the animal have large complex hemispheres of the brain, and at the same time very powerful posterior muscles, then both these conditions unite in demanding large lateral lobes of the cerebellum, and these organs, in fact, attain, under such circumstances,

their maximum development. This may be best illustrated by referring to Figs. 1 and 3, Man and the Dolphin. The other higher animals, who possess the same conditions, exhibit the same cerebellar ratio.

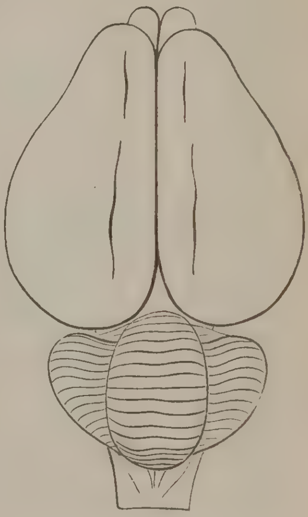
2. If the hemispheres of the brain be of a low grade, but the posterior extremities still powerful, then the deficiency in one condition is balanced by the excess in the other, and the animal will have lateral lobes bearing a moderate ratio of size with the median. One of the best examples of such a case is the Kangaroo. This animal like other marsupials is low in cerebral development, but it has a prodigous excess of power in the hinder extremities. Thus one condition balancing the other, the kangaroo is found to present a cerebellum whose lobes are tolerably well balanced in size.

Fig. 11.



Great Kangaroo—*Macropus Major.* (From Serres.)

Fig. 12.

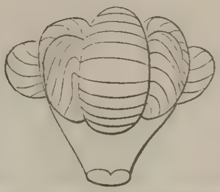


Agouti—*Chloromys.* (From Serres.)

In the Agouti, we have an animal in whom, I believe, there is no remarkable preponderance of either pair of limbs, but the hemispheres of the cerebrum are still lower in development than in the kangaroo. Accordingly we find a still further diminution of the lateral lobes.

In the common wild rabbit of the Illinois groves, the cerebrum is simple and small, but as in the kangaroo, the hinder extremities are predominant in power, as compared with the anterior. Here the conditions balance again, and the lobes of the cerebellum preserve a fair and moderate proportion among themselves.

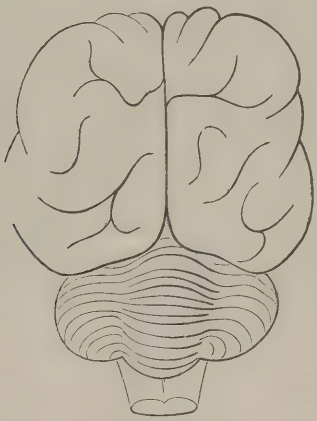
Fig. 13.



WILD RABBIT—*Lepus Sylvaticus.*

The Porcupine, *Hystrix cristata* presents an instance of a rather feebly developed cerebrum, which not being balanced by any unusual strength in the posterior extremities, results in a somewhat small pair of lateral lobes in the cerebellum.

Fig. 14.

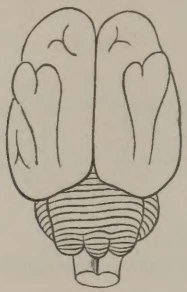


PORCUPINE—*Hystrix Cristata.* (From SERRES.)

3. If the animal have cerebral hemispheres of decidedly inferior development, and at the same time posterior limbs which are feebler than the anterior, then both conditions will coincide to reduce the lateral lobes to a bulk less than the median. This is well illustrated in the birds, Figs. 2 and 10; in the moles, Fig. 5, and in the bats, Figs. 7 and 9. Among larger animals it may be noticed in the encephalon of the sloth. This creature has anterior extremities some-

what more developed than the posterior, and at the same time very small cerebral hemispheres, both conditions demanding a predominant median lobe. Fig. 15 shows how well the law is carried out.

Fig. 15.

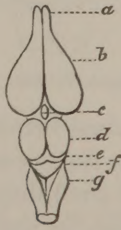


TWO-TOED SLOTH—*Bradypus Didactylus*. (From SERRES.)

It is proper to observe here, that in the view given, some portion of the lateral lobes is concealed from sight, so that the difference in size is not so exaggerated as at first appears.

In attempting to apply these laws to reptiles and fishes, we find great difficulties. The lobes of the cerebellum in the higher animals, constitute the chief bulk of the organ, and though they overlie several ganglia at their base, they are so much superior in size, as to manifest their relations quite clearly; but in the reptiles and fishes, the lobes are reduced almost to nothing, and the basal ganglia stand out and destroy the proportions of size. The cerebella of reptiles, however, are highly instructive in one point. They show us that the lateral and median lobes are in their simplest form, separate organs, having separate points of attachment to the cerebro-spinal axis. Fig. 16 is the brain of a small saurian, found

Fig. 16.



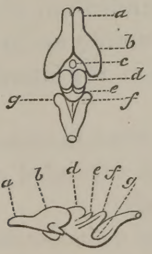
SAURIAN. Enlarged one diameter.

in the western States; *a*, is the olfactive ganglion; *b*, the cerebral hemisphere; *c*, the pineal body; *d*, the large anterior pair of the

tubercula quadrigemina; e, is the posterior pair of the same, and *f* is the whole cerebellum, as is generally asserted, but, as I think, represents only the median lobe. It is a small, flat, lunate lamina, supported by two peduncles, which run forwards—as the peduncles of the median lobe do in man—and are attached to the cerebro-spinal axis, beneath the tubercula quadrigemina. Behind, and upon each side of this we find a marked lateral prominence, which seems to me to represent the lateral lobe. It will be readily seen that, if the lateral lobes are as small in proportion, as the median, they would not constitute an organ at all larger than this ganglionic projection upon the *medulla oblongata*. It is clearly obvious, also, that the lateral lobes, in this case, belong to a position posterior to that of the median, although the median, leaning backward, in consequence of the pressure of the optic lobes, reposes its apex over the furrow directly between the lateral lobes. It is clear, also, that if these lobes were all to become largely developed, the median might adhere to the lateral, and occupy the position between them, which we see in higher animals. Thus, in the reptiles, we see the cerebellum analyzed, and displaying its typical form.

In the moccasin—a venomous snake found in Illinois—I find the lateral lobes projecting still more distinctly as a pair of tubercles, attached on either side of the *medulla oblongata*. Fig. 17 presents an upper and a side view of this brain, of the natural size. The letters refer to the same parts as in Fig. 16.

Fig. 17.



MOCCASIN—*Toxicophis piscivoris.*

Fig. 18 represents the brain of the sea turtle, of the species most used in our cities for food. Here we see the lateral and the median lobes much more perfectly developed than in the lower reptiles. The lobes adhere and fuse together, much as they do in birds, and leaving no line of demarcation, except a pair of very faint grooves

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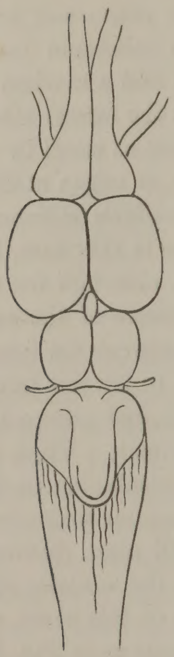
at the anterior part. The tendency of all these facts is to the following conclusions:—

Fig. 18.



SEA TURTLE.

1. The division of the cerebellum which we have been considering, is traceable from the reptiles up to man.

2. The typical position of the lateral lobes is posterior to the median.

3. The median lobe has some function connected with voluntary motion, and its influence is expended chiefly upon the muscles of the anterior half of the body.

4. The lateral lobes exert a similar influence over the muscles of the posterior half of the body, and they are also in some way connected with the mental functions, inasmuch as they are developed to a certain extent in direct ratio with the intelligence of the animal.

5. The *nature* of the influence exerted by the cerebellum upon the muscles is not very clear. Although it may be true, that through it the mind co-ordinates the muscular action, yet that is *not* true which is stated by Carpenter and others upon the subject,

viz., that the size of the cerebellum is in a direct ratio with the number and variety of co-ordinated movements which the animal is capable of exercising.

Within the limits already explained, the size of the cerebellum is *directly as the quantity and power of muscular fibre to be moved*, with no regard whatever to the simplicity or complexity of their combinations. Thus, the co-ordinated actions of a squirrel are far more numerous and varied than those of a dolphin. A mouse co-ordinates more than a bat; a rat more than a bird; a cat more than a seal; a sloth more than a sheep; yet in these, and in a hundred other instances, the animal which co-ordinates least, has the largest and most complex cerebellum—the ratio being as the bulk of muscle to be used, and in the case of the lateral lobes, partly as the grade of the intelligence of the creature. It seems to me, therefore, that, while it may be true that the mind, through the cerebellum, co-ordinates motions, it does not do so because it possesses a specific function of co-ordination, but simply because its action is directly excito-motor, and the mind through it can select any muscle, or set of muscles, it may choose for action.

Serres, in his experiments, cut the *lateral lobes*, and the result was that the voluntary power of the muscle of the opposite side was *positively weakened*, *especially in those of the posterior extremities.* There was, according to his account, a *loss of force*, a *partial paralysis*, and not merely a loss of co-ordination. It is not my purpose, however, to detail, in this report, the results of experiments.

The conclusions offered are simply as the *direction* in which the facts of comparative anatomy point; but not as in themselves decisive, unless they shall be confirmed by a new and full examination of the facts derivable from experiment and from pathology.